In this issue

Michael Faraday

Michael Faraday, whose bicentennial falls this year, is the *ultima Thule* of a scientist. His work is a perfect role model of what pure science can do. Of him it has been said,

> No experimental scientist has bequeathed to posterity a greater body of pure scientific achievements; and the practical consequences of his discoveries have profoundly influenced the very nature of civilized life.

C. N. R. Rao (**page 787**) pays a tribute to this incredible scientist. Many have said that, had there been Nobel prizes in his day, Faraday would have bagged at least six or seven. Further, each one of his fundamental discoveries led to the establishment of at least one class of industry (electrical, electrochemical, chemical and dye, optical glass, steel, vulcanization of rubber). Yet many feel that it is his concept of a field that transformed the face of science. The idea that attraction between two bodies is due to action at a distance was repugnant to Faraday. If magnets attract each other, Faraday felt that the attraction was due to a strain set up by the magnets in *space*. 'If this strain were to be released by starting or stopping a current which produced the magnetic field, what would happen?' It would be similar to cutting a tensioned wire, and the released tension should reach the other end in due course. To test this idea Faraday stopped a current in a magnetic coil and he discovered that there was a distinct effect on a coil he had placed in the neighbourhood. This was his famous discovery of electromagnetic induction. Faraday's guess that magnetic and electrical strain may take a perceptible time to travel in space led to the physical enunciation of the electromagnetic theory by James Clerk Maxwell, one of the greatest theoretical physicists. Maxwell converted Faraday's elegant idea into mathematics by introducing the idea of a stress tensor and deduced that light was an electromagnetic wave. All this and more are described by N. Kumar (**page 790**).

Transition

One of the most important political events of 1991 was the breakup of the Soviet Union. This, and the earlier fall of the communist governments in Eastern Europe are widely seen as representing a turning point in history. Admittedly, while the inevitability of the fall of the once mighty communist empire was almost a foregone conclusion after *glasnost* and *perestroika*, one cannot have prepared for all the consequences. In the area of science and technology, they threw up problems for those countries and for the international scientific community. One of the most visible consequences of the institution of market-oriented economies in these countries is the economic one—inflation, and the scarcity of hard currency. S&T communities that earlier had limited exposure to Western and world science now find themselves in need of money to buy equipment and journals, and to organize visits abroad. But what was S&T like under the communist rule, say in the Soviet Union? There are, of course, two pictures—one of much advance in some areas, such as space, lasers and magnetohydrodynamics; and the other of trailing behind the West in many areas, particularly electronics and the associated industries. C. K. Mathews, who visited the Soviet Union before the breakup, records his impressions (**page 804**). He also sees some similarities between the problems in the former Union and the situation in respect of S&T management in India. The most important negative aspects, according to Mathews, are the centralized decision-making and our system of rewards.

In another article, also written before the fall of the Soviet Union, Sergei Kapitza (**page 806**) looks at an almost diametrically opposite problem. This is the alarming rise in antiscience trends in his country. Kapitza argues that public antiscientific and antitechnological attitudes, encompassing superstitions, astrology, faith healing, UFOlogy and overbearing environmentalism (what Kapitza calls 'the irrational that is partially right'), are symptoms of a deep social malaise that also has to do with the nature of his country's transition.

Error-proofing design

The finite-element method (**page 813**) has now emerged as the most powerful computational technique for analysis and design in a very wide range of problems in engineering. It had its origins in the aerospace industry around the mid-fifties, particularly as a tool for handling problems in structural mechanics. The basic idea in the method is to replace the mathematical model of any physical problem, described in terms of differential equations and boundary conditions over a geometrically complex region, by breaking them down into simpler geometrical subdomains (called elements, the basic unit of discretization), over which the differential equations are substituted with discretized relationships. These can then be assembled and solved using special bookkeeping procedures that are very easily managed on a digital computer. Now there are very powerful general-purpose software packages available that make these analysis and design tasks very simple. These packages are at the core of computer-aided-design/computer-aided-manufacturing (CAD/CAM) systems, and are responsible for ensuring the integrity and economy of any design from the appropriate angle, such as structural mechanics, electromagnetism and fluid flow.

At the heart of the method is the process by which the governing differential equations are replaced by the discretized relationships which are to be expressed in the form of matrices. The accuracy and efficiency of solution will now depend on the robustness of this discretization process. In the early years of the method, one proceeded entirely from a combination of engineering intuition, heuristic judgement, and trial-and-error experimentation and validation. While the method was vastly successful in a very wide range of applications, there were spectacular failures also. These are the problems that came to be called the 'locking' problems. It was not clear why the method as it was then accepted, i.e. around 1977, should produce, for certain problems, such as the one considered in the article by Gangan Pratap, answers that were only a fraction of a per cent of the correct answer with a practical level of discretization. Pratap and coworkers, who examined this problem in considerable detail, have proposed a consistency paradigm. In this, the interpolation functions chosen to initiate the discretization process must also ensure that any special constraints that are anticipated must be allowed for in a consistent way. Failure to do this causes solutions to lock to erroneous physical limits. The group also provided error-analysis procedures that allowed errors to be traced to the inconsistencies in the representation and provided a scientific basis for evaluating elements. The paradigm showed how elements can be designed to be free of such errors. The author's group has now developed a family of such error-free robust elements for applications in structural mechanics.

Unexplained genius

The mathematical genius of Srinivasa Ramanujan continues to fascinate mathematicians and others. Fifty years after the publication of a mathematical biography by G. H. Hardy, Ramanujan's discoverer and friend, 'it is still too early to write a definitive mathematical biography, since too many of Ramanujan's results are still not understood', says Richard Askey, in a review of the recent biography bv Robert Kanigel (**page 844**). But Kanigel's biography, which also deals with Ramanujan's life and background and his interactions with other mathematicians, offers many insights while not entirely dispelling the 'feeling of strangeness' (Askey) about 'how Ramanujan discovered most of the gems he found'. Bruce Berndt and Robert Rankin, who are engaged in collecting Ramanujan correspondence and in writing commentary on the letters, explain their motivations and invite information (**page 792**).

Cost and benefit

The question of the cost of symbiotic nitrogen fixation to nodulated plants is still unresolved. The topic is of both scientific and technological interest, because photosynthetic carbon limitations on nitrogen fixation and an adverse effect of nitrogen fixation on overall crop yield are matters of agricultural productivity. Some studies on nodulated legumes have shown lower carbon cost of nitrogen fixation, i.e. more 'efficient' carbon usage, for plants that accumulated less dry matter. Mechanisms that regulate partitioning of photosynthate to various plant parts and to nodules may have a bearing on relative nitrogen and carbon accumulation. In general, photosynthate is allocated in proportion to sink strength. Nisha Garg *et al.* (**page 838**) look at the benefits of recycling hydrogen evolved in the energetically costly nitrogenase reaction. Nodule bacteroids that contain a functioning uptake hydrogenase (Hup^+) can couple energy (ATP) release to hydrogen recycling, thus conserving energy. This may result in lower relative translocation of assimilated CO_2 to nodules and overall photosynthate conservation. The authors compare partitioning of assimilated $^{14}CO_2$ in pea plants inoculated with Hup^+ and Hup^- rhizobia, and report slightly lower relative translocation of photosynthate to roots and nodules and higher overall dry matter and nitrogen content in plants inoculated with Hup^+ rhizobia. The Hup^+ trait may therefore be a desirable one in rhizobia used to inoculate legumes.